EVALUATION OF TECHNIQUES TO ESTIMATE CARCASS COMPOSITION OF BEEF CATTLE

By

REBECCA ANN ROSS

Bachelor of Science in Agriculture

Sam Houston State University

Huntsville, Texas

2003

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 2005

EVALUATION OF TECHNIQUES TO ESTIMATE

CARCASS COMPOSITION OF BEEF

CATTLE

Thesis Approved:

Clinton R. Krehbiel
Thesis Adviser

Gerald W. Horn

David L. Lalman

A. Gordon Emslie
Dean of the Graduate College

TABLE OF CONTENTS

LIST OF TABLES

Table Page

CHAPTER IV

LIST OF FIGURES

Figure Page

CHAPTER IV

ACKNOWLEDGEMENTS

I would like to thank Dr. Clint Krehbiel and Dr. Gerald Horn for all of their counsel and encouragement. Their support, guidance and mentorship was limitless. I thank Dr. Krehbiel for taking a chance on another unknown kid from Texas. I will be forever grateful for your frequent assistance and the unfaltering smile on your face. To Dr. Horn, my surrogate father, thank you for the unwavering emotional support and friendship. I feel very privileged to have had the opportunity to study under both of you. To Dr. Dave Lalman, thank you for your frequent encouragement, patience, and positive reinforcement.

To my fellow graduate students, I can only say thank you. I cannot express my gratitude in writing for the moral support offered by those whose names I need not mention. These actions reveal the ability of one to be a true friend. I wish all of you the best in your future careers and endeavors.

I would like to thank Kris Novotny, Joan Summers, Donna Perry, Trista Dye, Robyn Janloo, and Sandi Parr. I know that I need not say it, but this was all made possible with your laborious assistance, but most of all, your friendship.

To my family, whose emotional and financial support made all of this possible. I thank my parents for willingly creating me and raising me with the ability and desire to succeed. I have my mother to thank for her passion and my father for his steadfast support. If only all children were so lucky to be born into such a loving home. My sisters, you are my closest friends, a vital part of my soul and an integral part of my success.

This brings me to God, without whom I would not exist. God provided me service and support in the most mysterious and inconspicuous ways. God has played a big part in my failures and successes, and as a result, my placement in life. My undoubtedly planned journey to OSU led me to meet my fiancé, Ryan. I have God to thank for him. Without Ryan and his family, I would be incomplete. Thank you for encouraging me to believe in myself. Without your patience and understanding, I might never have reached this point.

CHAPTER I

INTRODUCTION

Estimating treatment or feeding regime effects on body composition in food producing animals continues to be an important area of research. Body composition of an animal resulting from previous nutrition and/or management programs can have profound effects on future performance. Nutrient requirements for production, maintenance of body condition, and gain are highly dependent on total body composition.

The need to measure carcass composition is a vital aspect of beef cattle research and production. Thus far, the most accurate and reliable method of estimating carcass composition appears to be direct determination of chemical composition. This process entails the total destruction of the carcass in preparation for lab analysis. Typically, the carcass is ground, dried and chemically analyzed. The use of total body grind and analyses to estimate composition is expensive, time consuming and wasteful of edible product. Therefore, intense pressure to develop more efficient and rapid methods has led to the proposal and continued research of many different procedures. Many alternate methods have been evaluated although none have been accepted and utilized exclusively in place of total chemical analysis. Each procedure has one or more limitations.

Some of the proposed methods include carcass specific gravity, 9-10-11 rib section analysis, urea dilution, and densitometry x-ray analysis. Specific gravity provides a measurement of body density to calculate percentages of water, crude protein, and fat.

Through 9-10-11 dissection and proximate analysis, proportions of water, crude protein, fat, and ash are measured. Equations have been developed to convert the proportions of water, crude protein, and fat of the rib section to values equaling that of the carcass. Densitometry x-ray scans predict carcass lean, fat, and ash. Lean is a measurement of crude protein and water. These scans can therefore be used to predict the composition of the rib section. *In vivo* dilution procedures such as urea, tritium, and deuterium oxide are used to predict body water. Equations have been developed using urea dilution measurements to determine empty body water, crude protein, and fat. Other animal measurements include estimation by body condition, USDA yield grade, ultrasound to determine backfat thickness, and antipyrine techniques. Each of these methods has distinct limitations.

For the present experiment, specific gravity, 9-10-11 rib section composition, and urea dilution were compared with carcass chemical analysis. Methods of estimating composition of the 9-10-11 rib section were also evaluated. The first method used to evaluate rib composition was the physical dissection of its components, and second was the densitometry x-ray analysis of the 9-10-11 rib section. The goal of this experiment was to provide evidence to confirm or contradict the reports that one or more of these methods does in fact produce accurate data.

The objective of this study was to evaluate the prediction capabilities of the abovementioned methods by determining the moisture, crude protein, and fat contents and compare each value to the actual chemical analysis of the carcass.

CHAPTER II

REVIEW OF LITERATURE

According to Hankins and Howe (1946) and Powell and Huffman (1968), the most reliable method for estimating the composition of an animal is the chemical analysis of the whole body. This procedure entails the grinding and laboratory analysis of the empty body (whole body, less gut contents) to determine the percentages of fat, crude protein, water, and ash. Murray (1922) suggested that most meat animals are of similar composition, with slight variations in protein, ash, and water, depending on age. According to Reid et al. (1955), age has a significant effect on the proportion of water, which decreases as an animal ages. The proportion of protein decreases with an increase in the deposition of fat, while ash as a percentage of body weight also decreases with maturity. As an animal matures, fat accretion increases (if nutritionally permitted), while decreasing the continued development of all other chemical components. The primary factor that differentiates individual animals is the fat content. Therefore, if the fat content could be determined, crude protein and water could also be estimated with reasonable accuracy.

Many factors influence body composition of beef cattle. The primary factors that influence composition are plane of nutrition, body weight, sex, age, and genetic potential for growth (Bruns et al., 2004). Plane of nutrition can change the composition and requirements of growing animals. As an animal undergoes compensatory growth, the

deposition of protein increases, although this phenomenon varies with age and severity of restriction (Carstens et al., 1991). Hammond (1932) and McMeekan (1940) characterized the order in which tissues are developed to be skeletal, muscle, and then fat. All tissues continue to develop, at varying rates, until maturity. Hopper (1944) suggested that at approximately 5 months of age the proportions of the components in the fat-free body are relatively constant. This suggests that if the fat content can be calculated, the proportions of protein, water, and ash of the fat-free body can be estimated. Fox and Black (1984) defined mature body weight as the point at which protein accretion ceases. As the age of an animal increases, there is a change in the ratio of moisture to protein. The protein content of the carcass increases with age, while the moisture content of the carcass decreases (Hopper, 1944), when comparing the fat-free body. Reid et al. (1955) suggested that the change in the proportion of water as an animal fattens is simply the replacement of water with fat. The deposition of fat is theorized to take place in a specified order, with internal fat first, followed by intermuscular, subcutaneous, and intramuscular (Andrews, 1958). Data from Bruns et al. (2004) contradicts the concept that intramuscular fat (marbling) is the last fat depot to develop. Their data suggested that marbling develops at a consistent rate under the normal growth curve when animals are on a high-energy finishing diet.

Hopper (1944) reported that moisture in the empty body of mature cows and steers ranged from 69.0 to 74.7 percent. He also reported that the range of protein was 20.6 to 22.0 percent and ash was 4.5 to 7.2 percent (DM basis). If these estimations of body components are accurate, then there was very little available for the fat component. Modern beef cattle are typically on a much higher plane of nutrition and therefore may

differ in composition. For instance, a beef cow at a body condition score of five would have an empty body composition of approximately 18.8 percent fat, 16.8 percent protein, 5.7 percent ash, and 61.4 percent water (NRC, 1996). There are two possible explanations for this difference. This is either a result of the differences in the technology available to estimate composition of food animals, or the difference in the composition of modern day food animals vs. animals used by Hopper (1994).

Lunt et al. (1985) emphasized the importance of developing a more efficient method for estimating body composition, in both live and harvested animals. It is important to establish a reliable and accurate relationship between the whole body, empty body and carcass of meat animals in order to summarize data that compares relationships between in vivo and in vitro measurements of body components (Hansard, 1968). Cattle types and breeds have changed since Hopper (1944) reported empty body composition values. More recent data from Alhassan et al. (1975) indicated that steers at an empty body weight of 306 to 325 kg have 53.2 to 53.9 percent empty body water, 24.6 to 26.9 percent empty body fat, 16.5 to 18.2 percent empty body protein, and 3.4 to 4.0 percent empty body ash. Though water, protein, and ash values are similar to those reported by Hopper (1944), body composition of cattle may currently be more variable due to breed development and nutritional improvement. Owens et al. (1995) suggested that modern cattle mature at higher body weights than cattle used for research in the early 1900s. Techniques that provided consistent results in the earlier 20th century may vary in accuracy due to the changes that cattle have undergone. Validation of techniques for measurement of body composition is necessary.

Methods of Estimation of Chemical Composition

Carcass Specific Gravity

Body specific gravity was introduced as an index of body fat by Behnke et al. (1942). Data from that investigation confirms that carcass density is an indicator of fatness. Fat is less dense than lean and bone, and therefore is responsible for deviations in weight when suspended in water. Specific gravity is a valuable tool for estimating body composition of research animals (Garrett, 1968). Garrett and Hinman (1969) reported high correlation coefficients and low standard errors indicative that specific gravity and carcass density may be strong predictors of carcass composition. Carcass specific gravity is a more accurate predictor of carcass composition than is carcass weight (Preston et al., 1974). The use of body specific gravity has been demonstrated and validated for its estimation of body fat in eviscerated guinea pigs (Rathbun and Pace, 1945). Kraybill et al. (1952) stated that estimating body composition of live mammals is difficult because of air retained in the lungs and gas production in the abdominal cavity. For this reason, their study used two variations of specific gravity measurement. They weighed the whole animal, less the viscera, as well as the dressed carcass. The values obtained from both measurements indicated that the dressed carcass is representative of the whole animal. This data agrees with the results from Rathbun and Pace (1945). One of the limitations associated with specific gravity is accuracy when weighing lean animals, which tend to yield less accurate results. Johnson et al. (1990) emphasized that values obtained from specific gravity measurements were most accurate with fat carcasses. Fat content is the primary factor influencing specific gravity measurements,

and therefore an accurate estimate of lean is difficult when little fat is present. Gil et al. (1970) found consistent results, in that fat animals (30 to 42% fat) had higher correlations between specific gravity, and the percent of water, protein and fat than younger, leaner animals. Gil et al. (1970) and Garrett and Hinman (1969) reported varying degrees of minimal fat percentages when measuring beef steers, with 20% and 12% respectively. Alhassan et al. (1975) developed equations that may be accurate in predicting body composition of thin cattle, given that many of the cattle in their study had body fat percentages less than 20. However, they emphasized that further investigation was necessary. Preston et al. (1974) investigated the reasoning behind the minimal fat concept and the relationship with bone proportionality; however, their results were inconclusive. Owens et al. (1995) emphasized that regardless of the possible difficulty in measurement due to degree of fatness, carcass specific gravity is one of, if not the most successful and proven technique to estimate carcass composition.

Ninth-Tenth-Eleventh Rib Section

In 1946, Hankins and Howe revisited a theory which Lush (1926) researched and Hopper evaluated in 1944. Hopper (1944) showed that the ninth-tenth-eleventh rib section and its edible portion were highly correlated with the physical and chemical composition of the carcass, especially that of fat. This is in agreement with Lush's (1926) research showing that fat content of the wholesale rib cut and the fat of the entire carcass are highly correlated. There were also suggestions by the United States Department of Agriculture, in 1935, that the percentage of bone in the dressed beef carcass could be estimated by the bone content of the ninth-tenth-eleventh rib section.

The USDA developed equations to predict bone by way of the 9-10-11 rib section and found a correlation coefficient of 0.83.

The results described by Hankins and Howe (1946) of the ninth-tenth-eleven rib section comparison exhibited a strong relationship between separable fat of the rib section with that of the dressed carcass, although these relationships were not as highly correlated for heifers (R^2=0.88) as for steers (R^2=0.93). The edible portion of the rib section had highly correlated ether extract values to that of total carcass fat. Estimation of lean of the carcass using the separable lean of the rib cut was highly correlated for steers (R^2=0.90). The determination of lean in heifers did not show such a strong correlation (R^2=0.72). However, the resulting standard error (2.51) led Hankins and Howe (1946) to conclude that the lean content of the rib cut was enough to estimate composition in heifers as accurately as that of steers. Separable bone of the rib section and that of the dressed carcass had an overall R^2=0.83. There was also a very strong relationship between the water content of the rib section and the dressed carcass (R^2=0.93). As for the ash content of the rib section, they did not find that the dressed carcass was accurately represented. Powell and Huffman (1968) evaluated the prediction equations reported by Hankins and Howe (1946) and concluded that it was in fact the most accurate method of estimating carcass fat and protein. This conclusion was based on the multiple methods evaluated by Powell and Huffman (1968), which compared the 9-10-11 rib section to yield grade and carcass specific gravity. Lunt and co-workers (1985) also concluded that the rib section was the most appropriate technique to estimate carcass composition as compared with carcass specific gravity, USDA yield grade, and deuterium oxide dilution.

Dual-Energy X-Ray Absorptiometry

Dual energy x-ray absorptiometry (DXA) has been developed and studied as a technique to estimate body composition in humans. It is a convenient, non-invasive procedure, which can produce very high precision with a minimal dose of radiation. This technology uses algorithms that distinguish between the high (70 keV) and low (38 keV) energy x-rays absorptive activity (Mitchell et al., 1997). It is currently the preferred method for estimating body chemical composition in humans (Chauhan et al., 2003). This technology provides an estimate for bone mass, density, fat and lean tissue mass. One problem associated with the DXA scan is the difficulty in validating data generated on thick tissues, varying in depth and composition (Lukaski et al., 1999).

Recent research has demonstrated a role for this technology in estimating chemical composition of meat animals. Research published by Mitchell et al. (1996, 1997, 1998 and 2003) demonstrated the ability of dual energy x-ray absorptiometry scans to predict body composition of swine and cattle. In 1996, this was attempted on the whole body of sacrificed pigs, with good results in the estimation of total fat (R^2=0.99) and lean body mass (R^2=0.97) as compared with chemical analysis. Estimates of total body mass were highly related to actual weight (R^2=0.99). The 1996 study yielded accurate estimates of lean, fat, and bone mineral content in half-carcasses. The 2003 study was similar to the 1998 study wherein the DXA scan of a cross-section of pork carcasses was highly correlated to total carcass composition. Mitchell et al. (1997) hypothesized that the DXA scan may accurately estimate the composition of beef tissues as well. A side of beef was too large to scan on the DXA machine; therefore, the ninth-tenth-eleventh rib section was chosen as a reasonable alternative. The results of this

study showed that the DXA scan overestimated the fat that was measured by dissection. This suggests that the machine may have experienced difficulty differentiating between lean and fatty tissue due to increased tissue depth. Lukaski et al. (1999) also concluded that the DXA scan significantly underestimated fat content of the carcass, when compared with chemical analysis, though percent fat was still highly correlated (R^2=0.91). Their study suggested that total tissue thickness of a scanned object, above the range of 16 to 28 centimeters, could be associated with the possible overestimation of fat and bone content, although they did not observe this in their data. Overall, however, Lukaski et al. (1999) showed significant correlations between the DXA results and chemical analysis. Mitchell et al. (1997) concluded that DXA is a valid approach when there is a desire to estimate chemical composition without de-boning or de-valuing the product; however, they emphasized the need for further investigations into equipment calibration.

In -Vivo Dilution

Many different methods of *in vivo* dilution have been developed and researched, such as tritium, deuterium oxide, and urea (Owens et al., 1995). Deuterium oxide dilution proposed by Byers (1979) is intended to estimate water content of the live animal. The results have been inconsistent, with the process found to be unreliable in a study by Lunt et al. (1985), while Andrew et al. (1995) found deuterium oxide superior to urea dilution. Meissner et al. (1980) found tritium dilution to yield more accurate results than urea dilution. Overall, however, urea offers multiple advantages over many of its counterparts. First, it is relatively inexpensive, non–toxic, and is a naturally occurring

compound found in the body (Wagner, 1985). Urea diffuses into cellular water and free water in the body within approximately 15 minutes, at which time urea concentration in the tissues is equal to that in the blood, and therefore aids in the measurement of body water (Preston and Kock, 1973). If body weight and percent of body water are known, body composition can be estimated by urea dilution measurements (Bartle and Preston, 1986).

Extensive studies have been performed using the urea dilution technique as developed by Preston and Kock (1973). Thus far, the results of urea dilution measurements have been relatively consistent in estimating empty body composition. Multiple equations have been published predicting empty body water in beef cattle, such as those by Preston and Koch (1973), Koch and Preston (1979), Meissner et al. (1980), Bartle et al. (1983), Hammond et al. (1984), Rule et al. (1986), and Bartle et al. (1987). Rule et al. (1986) suggested that the results from these studies provide significant evidence to support urea dilution as a suitable method for estimating empty body water.

Hammond et al. (1984) suggested that urea dilution is in fact an accurate estimator of body water; however, further investigation is necessary to accurately estimate protein and fat. One problem in using urea as an estimator is the unknown amount of urea equilibrating with water in the reticulo-rumen and the total amount disposed of in urine pools. Bartle and Preston (1986) concluded that urea does not diffuse into the gastrointestinal water in significant amounts when an animal has been fasted; however, this might be a source of variation in non-fasted animals. Bartle et al. (1983) reached a similar conclusion that gastrointestinal fill does influence the estimation of urea space.

Kock and Preston (1979) defined urea space as the volume of water with which urea equilibrates. Urea space may be calculated by extrapolation of plasma urea concentration back to time of infusion or it may be calculated by dividing amount of urea injected by the change in plasma urea concentration from the zero minute sample collected prior to urea infusion (Preston and Kock, 1973). One point of interest is the weight basis by which to measure urea space. Hammond et al. (1990) and Wells and Preston (1998) calculated values based on an empty body basis, while Bartle et al. (1987), Hammond et al. (1984) and Rule et al. (1986) found live weight to produce more precise results. Sources of variation between these calculations may be related to breed, sex and age of the cattle sampled. Various researchers have collected urea space measurements on various sexes and physiological conditions of cattle. Studies have been performed by Kock and Preston (1979), Hammond et al. (1984), Lunt et al. (1985), Rule et al. (1986), Hammond et al. (1988), and Wells and Preston (1998) on beef steers. Bartle et al. (1983) and Bartle et al. (1986) collected data on non-pregnant mature cows and on heifers, respectively. Meissner et al. (1980) collected data on bulls. Wuliji et al. (2003) used urea space to measure body composition in growing goats. The use of equations developed in beef cattle did not yield high correlation values in goats and therefore had to be modified to that specie. Their adjusted results were similar to those reported by Bartle et al. (1987), where body water was underestimated by 13%.

Kock and Preston (1979) and Hammond et al. (1988) used the 12-minute post-infusion sample to represent the point at which urea had equilibrated into the body. Kock and Preston (1979) found that urea space measurements collected at 12 minutes post-infusion provided a significant correlation between the composition of the rib section and

the specific gravity measurements, in all of the weight groups sampled. The use of urea space measurements to estimate body composition in cattle yields variable results, with many positive results and many poor results. Some conclude that this is due to differences in breed, sex, and physiological condition, which affect body composition. Further evaluation may be necessary to modify the equations reported by previous workers. Urea space may be accurate in different species with modified equations and further investigation.

Summary

The methods discussed above have been substantiated by thorough research and have provided an abundance of background into the possibilities that body composition research has to offer. The challenge faced by this research is solidifying the aforementioned reports with consistent data and accurate results. Without consistency and modification, none of the proposed methods will permanently replace total chemical analysis. The objective of the following report was to investigate and provide that data.

LITERATURE CITED

Alhassan, W. S., J. G. Buchanan-Smith, W. R. Usborne, G. C. Ashton, and G. C. Smith. 1975. Predicting empty body composition of cattle from carcass weight and rib cut composition. Can. J. Anim. Sci. 55:369-376.

Andrew, S. M., R. A. Erdman and D. R. Waldo. 1995. Prediction of body composition of dairy cows at three physiological stages from deuterium oxide and urea dilution. J. Dairy Sci. 78:1083-1095.

Andrews, F. N. 1958. Fifty years of progress in animal physiology. J. Anim. Sci. 17:1064-1078.

Bartle, S. J., S. W. Kock, R. L. Preston, T. L. Wheeler and G. W. Davis. 1987. Validation of urea dilution to estimate in vivo body composition n cattle. J. Anim. Sci. 64:1024-1030.

Bartle, S. J. and R. L. Preston. 1986. Plasma, rumen, and urine pools in urea dilution determination of body composition in cattle. J. Anim. Sci. 63:77-81.

Bartle, S.J., J.R. Males and R.L. Preston. 1983. Evaluation of urea dilution as an estimator of body composition in mature cows. J. Anim. Sci. 56:410-417.

Behnke, A. R., B. G. Feen and W. C. Welham. 1942. Specific gravity of healthy men. J. Am. Med. Assoc.118:495.

Bruns, K. W., R. H. Pritchard and D. L. Boggs. 2004. The relationship among body weight, body composition, and intramuscular fat content in steers. J. Anim. Sci. 82:1315-1322.

Byers, F. M. 1979. Measurement of protein and fat accretion in growing beef cattle through isotope dilution procedures. Page 36 *in* Ohio Beef Cattle Res. Progress Rep. Anim. Sci. Ser. 79. Ohio Agr. Res. Dev. Ctr., Wooster.

Carstens, G. E., D. E. Johnson, M. A. Ellenberger and J. D. Tatum. 1991. Physical and chemical components of the empty body during compensatory growth in beef steers. J. Anim. Sci. 69:3251-3264.

Chauhan, S., W. W. K. Koo, M. Hammami, and E. M. Hockman. 2003. Fan beam dual energy x-ray absorptiometry body composition measurements in piglets. J. Am. College Nutr. Vol. 22, No. 5:408-414.

Fox, D. G. and J. R. Black. 1984. A system for predicting body composition and performance in growing cattle. J. Anim. Sci. 58:725-739.

Garrett, W. N. 1968. Experiences in the Use of Body Density as an Estimator of Body Composition of Animals. Pages 170-186 in Body Composition in Animals and Man. Natl. Academy of Sci. Pub. 1598.

Garrett, W. N. and N. Hinman. 1969. Re-evaluation of the relationship between carcass density and body composition of beef steers. J. Anim. Sci. 28:1-5.

Garrett, W. N., J. H. Meyer and G. P. Lofgreen. 1959. The comparative energy requirements of sheep and cattle for maintenance and gain. J. Anim. Sci. 18:528-547.

Gil, E. A., R. R. Johnson, V. R. Cahill, K. E. McClure and E. W. Klosterman. 1970. An evaluation of carcass specific volume, dye dilution and empty body parameters as predictors of beef carcass composition over a wide range of fatness. J. Anim. Sci. 31:459-469.

Hammond, A.C., D.R. Waldo and T. S Rumsey. 1990. Prediction of body composition in holstein steers using urea space. J. Dairy Sci. 73:3141-3145.

Hammond, A. C. T. S. Rumsey and G. L. Haaland. 1984. Estimation of empty body water in steers by urea dilution. Growth 48:29-34.

Hammond, J. 1932. Growth and development of mutton qualities in the sheep. Oliver and Boyd, Edinburgh, Scotland.

Hankins, O.G. and P.E. Howe. 1946. Estimation of the composition of beef carcasses and cuts. USDA Tech Bull. 926: 1-20.

Hansard, S. L. 1968. Dilution Methods in Body-Composition. Pages 195-199 in Body Composition in Animals and Man. Natl. Academy of Sci. Pub.1598.

Hopper, T. H. 1944. Methods of estimating the physical and chemical composition of cattle. J. Agr. Res. Vol. 68, No. 6:239-268.

Johnson, L.P., M.F. Miller, K.D. Haydon and J. O. Reagan. 1990. The prediction of percentage of fat on pork carcasses. J. Anim. Sci. 68:4185-4192.

Kock, S. W. and R. L. Preston. 1979. Estimation of bovine carcass composition by the urea dilution technique. J. Anim. Sci. 48:319-327.

Kraybill, H. F., H. L. Bitter and O.G. Hankins. 1952. Body composition of cattle. II. Determination of fat and water content from measurement of body specific gravity. J. Appl. Physiol. 4:575-583.

Lukaski, H. C., M. J. Marchello, C. B. Hall, D. M. Schafer, W. A. Siders. 1999. Soft tissue composition of pigs measured with dual x-ray absorptiometry: Comparison with chemical analyses and effects of carcass thickness. Nutrition. Vol. 15, No. 9: 697-703.

Lunt, D.K., G.C. Smith, F.K. McKeith, J.W. Savell, M.E. Riewe, F.P. Horn and S.W. Coleman. 1985. Techniques for predicting beef carcass composition. J. Anim. Sci. 60: 1201-1207.

Lush, J. L. 1926. Practical methods of estimating proportions of fat and bone in cattle slaughtered in commercial packing plants. J. Agric. Res. 32:727-755.

McMeekan, C. P. 1940. Growth and development in the pig, with special reference to carcass quality characteristics. II. The influence of the plane of nutrition on growth and development. J. Agric. Sci. (Camb.) 30:387-443.

Meissner, H. H., J. H. Van Staden and E. Pretorius. 1980. In vivo estimation of body composition in cattle with tritium and urea dilution. II. Accuracy of prediction equations of the chemical analyzed carcass and non-carcass components. S. Afr. J. Anim. Sci. 10:165-173.

Mitchell, A. D., A. M. Scholz and V.G. Pursel. 2003. Prediction of pork carcass composition based on cross sectional region analysis f dual-energy x-ray absorptiometry (DXA) scans. Meat Science. 63:265-271.

Mitchell, A. D., A. M. Scholz, V. G. Pursel and C.M. Evock-Clover. 1998. Composition analysis of pork carcasses by dual-energy x-ray absorptiometry. J. Anim. Sci. 76:2104-2114.

Mitchell, A. D., M.B. Solomon and T.S. Rumsey. 1997. Composition analysis of beef rib sections by dual-energy x-ray absorptiometry. Meat Science. 47:115-124.

Mitchell, A. D., J.M. Conway and W. J. E. Potts. 1996. Body composition analysis of pigs by dual-energy x-ray absorptiometry. J. Anim. Sci. 74:2663-2671.

Murray, J. A. 1922. The chemical composition of animal bodies. J. Agr. Sci. 12:103-110.

NRC. 1996. Page 36 in Nutrient Requirements of Beef Cattle. 7th rev ed. Natl. Acad. Press, Washington, DC.

Owens, F. N., D. R. Gill, D. S. Secrist, and S. W. Coleman. 1995. Review of some aspects of growth and development of feedlot cattle. J .Anim. Sci. 73:3152-3172.

Powell, W. E. and D. L. Huffman. 1968. An evaluation of quantitative estimates of beef carcass composition. J. Anim. Sci. 27:1554-1558.

Preston, R.L. and S.W. Kock. 1973. In vivo prediction of body composition in cattle from urea space measurements. Proc. Soc. Exp. Biol. Med.143:1057-1061.

Preston, R. L. R. D. Vance, V. R . Cahill and S. W. Kock. 1974. Carcass specific gravity and carcass composition in cattle and the effect of bone proportionality on this relationship. J. Anim. Sci. 38:47-51.

Rathbun, E. N. and N. Pace. 1945. Studies on body composition. I. Determination of body fat by means of the body specific gravity. J. Biol. Chem. 158:667-676.

Reid, J. T., G. H. Wellington and H. O. Dunn. 1955. Some relationships among the major chemical components of the bovine body and their application to nutritional investigations. J. Dairy Sci. 12:1344-1359.

Rule, D. C., R. N. Arnold, E. J. Hentges and D. C. Beitz. 1986. Evaluation of urea dilution as a technique for estimating body composition of beef steers in vivo: Validation of published equations and comparison with chemical composition. J. Anim. Sci. 63:1935-1949.

USDA. 1935. Report of the chief of the bureau of animal industry. 55 pp.

Wagner, J. J. 1985. Carcass composition in mature Hereford cows: estimation and influence on metabolizable energy requirements for maintenance during winter. pp. 16-18. Ph. D. Diss., Oklahoma State Univ., Stillwater.

Wells, R.S. and R.L. Preston. 1998. Effects of repeated urea dilution measurement on feedlot performance and consistency of estimated body composition in steers of different breed types. J. Anim. Sci. 76:2799-2804.

Wuliji, T., A.L. Goetsch, R. Puchala, T. Sahlu, R.C. Merkel, G. Detweiler, S. Soto-Navarro, J. Luo, T. Shenkoru. 2003. Relationships between body composition and shrunk body weight and urea space in growing goats. J. Appl. Anim. Res. 23:1-24

CHAPTER III

MATERIALS AND METHODS

Introduction

This research project was part of a broader experiment conducted to evaluate the effects of various growing programs on performance, carcass merit, whole body, carcass, and offal composition, splanchnic organ mass, and maintenance energy requirements during the growing and subsequent finishing phases of beef cattle production. A total of 260 steers were used for this experiment. The present experiment used a subset (n = 46) of steers from the broader experiment to compare methods of estimating carcass composition to actual composition of the carcass as determined by grinding and chemical analysis. This chapter describes the materials and methods used to compare methods of estimating carcass composition of steers on various feeding regimes before and after the finishing phase of production.

Experimental Animals and Treatments

Fifty Angus x Hereford steers from the Oklahoma State University cowherd were used for the experiment. An additional 210 steers of similar biological type and age were purchased by Continental Beef Research, Lamar, CO. Steers were blocked by weight and randomly allotted to one of four treatment groups (64 steers/treatment) or to an initial slaughter group (n = 4). The initial steers were slaughtered on November 12, 2003. Dietary treatments used in the study included: 1) wheat pasture followed by feedlot

finishing (**WP**); 2) sorghum-silage-based growing diet followed by feedlot finishing (**SS**); 3) high-energy diet fed at amounts programmed to allow similar live weight gain as observed for treatments one and two during the growing phase followed by feedlot finishing (**PF**); or 4) high-energy finishing diet (**CF**). Average initial body weight (kg) for the three growing phase groups were as follows: WP, 252.7±6.4; SS, 236.8±6.4; and PF, 234.6±6.4. The initial body weight for the CF finishing phase steers was 239.1±10.8 kg. Diet composition was reported by McCurdy et al. (2005). After all steers were assigned to their respective treatment groups, 12 steers each from the WP, SS, and PF treatment groups, and six steers from the CF treatment group were randomly selected for determination of carcass composition. All steers consuming growing or finishing feedlot diets were fed at Continental Beef Research. Wheat pasture grazing occurred at the Oklahoma State University Wheat Pasture Research Unit, Stillwater.

At the end of the growing phase (approximately 112 d), steers from all treatment groups were adapted to the high-concentrate finishing diet and placed in the feedlot (n = 8 pens; 7 or 8 steers/pen). At the initiation of the feedlot phase, six steers each from the WP, SS, and PF treatment groups, which had been randomly assigned for slaughter and subsequent determination of body composition, were delivered to the Willard Sparks Beef Research Center (**WSBRC**), Stillwater, OK. To facilitate sample collection, two steers/treatment (six steers total) were delivered to the WSBRC at weekly intervals on March 15, 22, and 29, 2004. Steers transported to the WSBRC remained on their respective treatment diets. Because CF steers reached their finishing point earlier than steers from other treatments (191 vs. 219 to 233 total days on study, respectively), no intermediate harvest group was selected from the CF group. At the time of final

slaughter, six steers/treatment were delivered to the WSBRC for determination of urea space and subsequent carcass composition. Slaughter dates were May 27, 2004 for CF steers, June 24 (three steers/treatment) and July 1 (three steers/treatment), 2004 for SS and PF steers, and July 21, 2004 for WP steers. After the finishing phase, all remaining steers from all treatment groups were slaughtered commercially at a common backfat of 1.27 cm as determined by ultrasound.

Urea Dilution

With the exception of the initial harvest group, the urea dilution technique (Bartle et al., 1987) was conducted one day prior to harvest on all steers slaughtered for determination of carcass composition. Feed, but not water, was removed from steers the evening (approximately 12 h) before the procedure. The morning of urea dilution, steers were individually weighed, and a temporary jugular catheter (Bolab Products, Lake Havasu City, AZ) was placed in the right jugular vein. The weight obtained at this time was used as the final live weight of the animal. A 10-mL blood sample was taken prior to urea infusion (0 h) with a 10-mL latex free syringe (Becton Dickinson & Co. Franklin Lakes, NJ). Steers were infused (0.66 mL/kg BW) with an autoclaved, 20% urea (w/v), 0.9% saline (w/v) solution within a 2-min period as described by Bartle et al. (1987). Ten milliliters of a heparinized (157 U/mL) 0.9% saline solution was used to flush the catheter following the infusion of the urea solution. Consecutive 10 mL blood samples were taken at 9, 12, and 15 min after infusion. The heparinized saline solution was cleared from the catheter before each sampling by withdrawing and discarding 10 mL of blood before the sample was collected. Each blood sample was collected into a 10-mL

syringe and transferred into a 16 x 100 mm sterile vacutainer tube, containing 15% EDTA (Sherwood Medical, St. Louis, MO). The heparinized solution was replaced after each sampling.

Blood samples were centrifuged at 3,000 x *g* to separate the plasma. Plasma was harvested and frozen at -20°C until analysis. Urea concentration (m*M*) of each plasma sample was determined using a colorimetric method modified from the Pointe Scientific Blood Urea Nitrogen kit (Pointe Scientific, Canton, MI). A stock standard was mixed at 100 m*M* and five dilutions were prepared using concentrations of urea at 2, 4, 6, 8, and 10 m*M*. All urea concentrations were determined using a UV/VIS Spectrophotometer DU Series 530 (Beckman Instruments; Fullerton, CA) at 600 nm.

Slaughter Procedures

Steers were transported to the Food and Agricultural Products Research and Technology Center (***FAPC***) on the morning of harvest. Slaughter procedures were similar to those described by Hersom et al. (2004). The live weight measured prior to urea dilution less the weight of the gastrointestinal contents was used as the measurement for empty body weight. Briefly, after stunning and exsanguinations, weights of all non-carcass tissues (blood, feet and ears, hide, all organs, and visceral fat) and **HCW** were recorded. Each portion of the empty gastrointestinal tract was weighed and recombined with visceral fat (mesenteric and omental), and ground twice through the 1.27-cm aperture plate of an 801GHP grinder (Autio Company; Astoria, OR), mixed, and subsampled in triplicate. The remaining ground gastrointestinal tract and visceral fat

were subsequently recombined with offal tissues and ground twice using an Autio grinder through a 10-mm aperture plate, mixed, and subsampled in triplicate.

After a 48-h chill, carcasses were reweighed (***CCW***) and carcass characteristics were evaluated by Oklahoma State University meat science faculty. Subsequently, the 9-10-11 rib section was separated from the right side of the carcass. The procedure was performed as described in Hankins and Howe (1946). The rib section was weighed, vacuum packaged, and stored at -20°C until analyses. The remaining right side of each cold carcass was ground through a 10-mm followed by a 5-mm aperture plate, mixed, and subsampled in triplicate.

Triplicate samples of the carcass were analyzed for water content by lyophilization to a constant weight. Lyophilized carcass samples were further processed to reduce particle size by submersion in liquid nitrogen and ground using a commercial blender (Waring Products Co., Winsted, CT). Carcass and offal tissues were subsequently analyzed for fat (extraction with petroleum ether for 48 h in Soxhlet apparatus), fat-free organic matter (**FFOM**; combustion of ether extraction residue, 500°C for 8 h), and N concentration (TruSpec Carbon/Nitrogen Analyzer, LECO, St. Joseph, MI).

Specific Gravity

The left side of each carcass was utilized for measurement of specific gravity. Left sides of the carcasses from steers harvested in November (initial) and March

(growing) were split into the forequarter and hindquarter for the weighing procedure. Left sides of carcasses from steers harvested in May, June, and July (finished) were split into four sections; the round, loin, rib, and chuck. Each section was weighed independently in air and then individually suspended in a tank (1.82 m long x 1.22 m deep x 0.58 m wide) of water at approximately 2°C. Each section was suspended by a hook and string, and the weight was recorded on an XL-6100 balance (Denver Instruments, Denver, CO) placed over the top of the tank. The flank and fat pockets were split in order to relieve any trapped air and avoid erroneous weights. Each side was allowed time to settle individually in the water until a stable weight (g) could be recorded. Carcass specific gravity was calculated by dividing the weights of the combined sections in air (kg) by the difference between the combined weights in air and the combined weights (g) in water (Garrett and Hinman, 1969). The value obtained from this measurement was used to calculate chemical values for the carcass.

Ninth-Tenth-Eleventh Rib Section

At the time of analysis, the frozen rib sections were defrosted, weighed, and transported to the Oklahoma State University Poultry Science Research Center. The 9-10-11 rib sections were then scanned using a Densitometry X-Ray Scanner, Hologic QDR 4500A (Hologic, Inc., Waltham, MA). The instrument was developed for infant whole body scans. Four rib sections were placed on the instrument at one time. Each scan was repeated four times to reduce the variability among readings. This provided four separate overall readings of each rib section, allowing the outlying measurements to be discarded. Each reading provided the following data: total area (cm^2), total mass (g),

bone mineral density (g/cm^2), bone mineral content (g), lean + bone mineral content (g), and fat (g and %). When all rib sections had been scanned, they were immediately returned to FAPC, where they were individually dissected into four separate components: bone (A), lean (B), fat (C), and mixed (D). The mixed component was the lean and fat component that could not be easily separated. Bone also contained heavy connective tissue. All components were individually weighed, re-vacuum packed and frozen at (-20°C) until further analyses could be conducted.

For analyses, components were thawed, removed from the vacuum pack, and weighed. Each component was passed individually through the 1.27-cm plate of the Autio 801GHP grinder. Sub-samples of each component were collected in duplicate. Sub-samples varied in weight depending on the weight of the rib section; therefore, 10 percent of the total weight of each component was sampled in order to collect a proportional amount from each rib section. After each component had been weighed and sub-sampled, the remaining 90 percent of each of the four components were combined and reground twice in order to ensure a uniform sample. Two 400-g samples were collected from this total grind. The remaining portion was sampled and stored vacuum packaged as a back up. Component D and the total grind samples were lyophilized to remove moisture and analyzed for N, fat, and FFOM content as previously described for carcass samples.

Calculations

Chemical composition of the carcass was used as the standard for which to compare the various methods of estimating total carcass composition. The three sub-

samples of the total carcass grind were analyzed separately and averaged to account for variation among replicates. Duplicates of the subsamples were analyzed and analyses were repeated when the coefficient of variation exceeded 5.0 percent. Percent N was multiplied by 6.25 to determine crude protein content. Percentage values obtained from lab analyses were multiplied by cold carcass weight to calculate the total kilograms of water, crude protein, fat, and ash in the carcass. To account for the contribution of the 9-10-11 rib section to the right side of the carcass, the weight of that section was multiplied by its respective chemical component percentages and the weight of each component was added back to the total carcass components.

Prediction equations used to calculate carcass composition from various methods are shown in Table 1. Urea space on an empty body and live weight basis was calculated from the equations described by Bartle et al. (1987) based on the plasma urea concentration (**PUN**) in the 12-min blood sample. The equation was as follows: mg urea-N infused/(change in PUN concentration x empty body weight x 10). The prediction equations developed by Bartle et al. (1987) were used to convert urea space on an empty body basis to percent water, N, and fat. The measurements from three steers were removed from the model due to erroneous values. This resulted in a sample size of 39.

For specific gravity, we assumed that the chemical composition of the carcass was equal between the right and left sides. Specific gravity measurements were collected on all 46 animals, 48 h after slaughter. The weights obtained from measurements in air and measurements in water were used to calculate a value for specific gravity as previously described by Garrett and Hinman (1969). Garrett and Hinman (1969) developed equations to predict whole body components, empty body components, and carcass

components from specific gravity. The equations for carcass composition were used for the present experiment (Table 1).

The chemical analysis values (percentage of water, protein, and fat) of the 9-10-11 rib section were used to determine chemical composition of the carcass by equations developed by Hankins and Howe (1946) and Bruns et al. (2004). Two alternate methods were also used to estimate the composition of the rib section. Dual-energy x-ray absorptiometry was used to predict the weight of the rib section, as well as the percent lean, fat, and ash. The lean component determined represents the sum of crude protein and water. The instrument was developed and modified to predict the composition of poultry carcasses. Following the DXA scan, the rib section was dissected. Weights obtained from the dissections of lean and fat and the chemical analysis of the mixed component were compared to the actual composition of the rib section.

Statistical Analysis

All data obtained from chemical analysis of the carcass, urea space, specific gravity, and the 9-10-11 rib section were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). The initial model included diet, slaughter group (initial, growing, and finishing), method, and all of the two- and three-way interactions. Steer was considered a random effect. Diet x slaughter group nested within steer was included in the model and used to test the effects of diet, slaughter group, and diet x slaughter group. Residual error was used to test the effects of method and the interactions of method with diet and slaughter group. Diet did not interact with slaughter group and method, and therefore diet was removed from the model. The subsequent model included

slaughter group, method, and slaughter group x method. Slaughter group nested within steer was used to test the effects of slaughter group. When the slaughter group x method interaction was significant ($P < 0.05$), differences (least significant difference; $P < 0.05$) among methods were tested within each slaughter group. When slaughter group and method effects, but not the interaction, were significant, means were separated by LSD ($P < 0.05$). Results were considered significant at $P \leq 0.05$.

To assess the relationships between methods of estimating carcass composition and carcass composition determined from proximate analyses, the dependent variable of carcass composition was regressed on the independent variables of urea space (on an empty body weight basis), specific gravity, and the 9-10-11 rib composition using the PROC REG linear regression procedure of SAS Release 9.1.

CHAPTER IV

RESULTS

Total Carcass Composition

There were no slaughter group x method interactions ($P \geq 0.10$) for BW, HCW, CCW, and carcass water, fat, and ash of steers (Table 2). Body weight, HCW, and CCW were greater ($P < 0.05$) for steers following the growing phase than steers slaughtered initially, and were greater ($P < 0.05$) for steers at finishing than following the growing phase. Percent water in the carcass was similar ($P > 0.10$) between initial steers and steers slaughtered after the growing phase; however, percent carcass water was lower in steers slaughtered at finishing. Mass (kg) of carcass water increased ($P < 0.001$) as weight of the carcasses increased (finish > growing > initial slaughter groups). Similar to carcass water, percent ash in the carcass was similar between initial steers and steers slaughtered after the growing phase; however, percent ash was lower in steers slaughtered at finishing. Percent fat in the carcass was greater ($P < 0.05$) in steers slaughtered after the finishing phase compared with steers harvested initially or after the growing phase. Carcass fat mass increased ($P < 0.001$) as carcass weight increased (finish > growing > initial slaughter groups).

Evaluation of Methods

Mean comparisons of methods used to estimate carcass composition are shown in Tables 3 and 4. Estimates of carcass water (% and kg) were similar ($P > 0.10$) between proximate analysis and specific gravity; however, estimates of carcass (9-10-11 rib proximate analysis) and empty body (urea space) water were greater ($P < 0.05$) than for total carcass proximate analysis. Estimates of carcass fat (% and kg) were greater ($P < 0.05$) for specific gravity than proximate analysis, whereas estimates of carcass and empty body fat from 9-10-11 rib proximate analysis and urea space, respectively, were similar ($P > 0.10$) to carcass proximate analysis.

There was a growing phase x method of estimation interaction for carcass CP expressed both as percent ($P = 0.004$) and as kg ($P < 0.001$; Table 4). This most likely resulted from similar ($P > 0.10$) estimates of CP by specific gravity and 9-10-11 rib CP analysis for the initial slaughter group, similar ($P > 0.10$) estimates of CP by urea dilution, specific gravity, and 9-10-11 rib analysis for steers slaughtered after the growing phase, and differences ($P < 0.01$) between estimates of CP composition for steers slaughtered at finishing. Within each slaughter group, mean carcass CP estimated from specific gravity, 9-10-11 rib proximate analysis, and urea space (empty BW) was lower ($P < 0.05$) than carcass CP (% and kg) measured by carcass proximate analysis.

Relationships of carcass fat from proximate analysis to carcass fat estimated from urea space, specific gravity, and 9-10-11 rib proximate analysis are shown in Figures 1, 2, and 3. In the present experiment, the slope of the regression line for the relationship of carcass fat vs. empty body fat estimated from urea space did not differ ($P = 0.25$) from zero, suggesting this method was not efficacious for estimating carcass fat of growing and finishing steers (Figure 1). However, when carcass fat was related to fat estimated

from specific gravity (Figure 2) or 9-10-11 rib proximate analysis (Figure 3), 70 and 65%, respectively, of the variation could be accounted for ($P < 0.001$). Similar to carcass fat, the slope of the regression line for the relationship of carcass protein vs. empty body protein estimated from urea space did not differ ($P = 0.25$) from zero (Figure 4). Variation accounted for by equations relating carcass protein to carcass protein estimated using specific gravity ($R^2 = 0.33$; $P < 0.001$; Figure 5) or 9-10-11 rib proximate analysis ($R^2 = 0.39$; $P < 0.001$; Figure 6) was similar.

Composition of the Ninth-Tenth-Eleventh Rib Section

Slaughter group x method interactions ($P < 0.01$) were observed for all methods used to compare chemical compostion of the 9-10-11 rib section (Table 5). The DXA scan estimated weight of the rib section was similar ($P > 0.10$) in the initial slaughter group; however, it slightly overestimated ($P < 0.05$) weight in steers slaughtered after growing, and slightly underestimated ($P < 0.05$) weight of the rib section of finished steers.

There was a significant interaction between phase and method for fat (% and kg; $P < 0.001$). Dual-energy x-ray absorptiometry overestimated ($P < 0.05$) the fat content of the rib section for steers slaughtered after growing and finishing, whereas DXA was similar ($P > 0.10$) to proximate analysis for the initial group. Percent fat was underestimated ($P < 0.05$) in initial and steers slaughtered after growing, but was intermediate to proximate analysis and DXA in steers slaughtered at finishing. Numerical differences for fat mass followed a similar trend. Percent lean was similar ($P > 0.10$) between 9-10-11 rib proximate analysis and the DXA scan in the initial steer

group. However, the DXA scan underestimated ($P < 0.01$) lean in ribs from the growing and finishing steers. Lean (% and kg) was underestimated by 9-10-11 rib dissection in all slaughter groups.

The DXA scan also predicted the amount of ash in the rib section. There was a slaughter group x method interaction ($P < 0.001$) for ash content in the rib. The DXA scan underestimated ($P < 0.05$) the percent of ash following the growing phase, and underestimated the kg of ash during the finishing phase.

The relationships between percentage of lean or fat in the 9-10-11 rib section to that predicted by the DXA scan or physical separation are shown in Table 6. More than 70% of the variation in 9-10-11 rib fat could be accounted for fat estimated by DXA or dissection ($P < 0.001$). The relationship between percentage lean from DXA ($R^2 = 0.67$) or the dissection of the rib section ($R^2 = 0.63$) and chemical composition was also significant ($P < 0.001$).

CHAPTER V

DISCUSSION

Total Carcass Composition

Techniques evaluated in the present experiment were compared to actual carcass chemical composition. The composition data obtained from the chemical analysis of each slaughter group falls within the range of previous reports (Owens et al., 1993; NRC, 1996). Analysis of actual chemical composition in the present experiment eliminates the possibility that prediction methods may have produced inconsistent results due to atypical variation within slaughter group.

One possible source of variation between measurements of one component by any particular method may have been the expression of composition by mass (kg) vs. percentage. It is more appropriate from a biological standpoint to measure on a percentage basis because that measurement is proportional to the animal's size and stage of development. As an animal ages, each body component increases in mass, but not necessarily in direct proportion to body weight (Bartle et al., 1987). Owens et al. (1993) reported estimates of body composition of steers at increasing body weights. Their data indicated that a steer at approximately 200 kg of empty body weight has 20 percent fat and 17.5 percent protein. According to Owens et al. (1993), a steer at 330 kg of empty body weight has approximately 21 percent fat and 16 percent protein. A steer at 550 kg of empty body weight is composed of approximately 15 percent protein and 25 percent

fat. Owens et al. (1993) demonstrated that the proportion of empty body fat in cattle increases as empty body weight increases, whereas proportion of body protein decreased. In the present experiment, we observed an increase in proportion of fat. For proportion of water and fat, the lack of a slaughter group by method interaction suggests that all methods were able to estimate the increase in these components. However, for crude protein, there was little detection of the proportional change. The percentage of CP decreased as the animals grew and fattened, resulting in the significant phase by method interaction.

The differences in the live body weight, hot carcass weight, and cold carcass weights between the slaughter groups were expected. All three measurements increased substantially between the slaughter groups from initial to finish. Water, fat, and CP increased in mass (kg) between slaughter groups, relative to phase of production. There was similarity in the percentage of water between the initial and growing phases, whereas the percentage of water decreased in the final slaughter group. This is in agreement with Reid et al. (1955) who showed that the decrease in the proportion of carcass water is in direct relation to the increase in accretion of fat. Similar to Bartle et al. (1987), mass of carcass components, such as moisture, protein, and fat, increased with age in the present experiment, but not necessarily as a proportion of body weight. Water and protein decreased and fat increased as a proportion of body weight. Initial and growing slaughter groups had similar composition, whereas the finished steers were significantly larger and therefore had a larger overall mass (kg) of water. The percentage of ash between the initial and growing steers was also similar, whereas the final slaughter group had a lower percentage of ash. Ash followed a similar pattern to the percentage of water in the

carcass. As animals age, the accretion of protein, water, and ash decreases and the percentage of fat in the carcass increases (Reid et al., 1955). This pattern was also observed in the present study. The percentage of fat between the initial and growing phases did not differ, while the finished steers had a greater percentage of fat. The mean mass of fat increased with each slaughter group as previously reported by Owens et al. (1993) and the NRC (1996).

Methods of Estimating Chemical Composition

All of the carcass prediction methods provided estimates of water, protein, and fat composition. Urea space calculations were based on empty body weight, while cold carcass weight was used for chemical composition, specific gravity, and the 9-10-11 rib section composition. These measurements were utilized to calculate the mass (kg) of respective components. Of techniques used in the present experiment to predict water, specific gravity of one side of the carcass provided the highest coefficient of determination and the most accurate value when compared to carcass chemical analysis, although the R^2 values obtained from specific gravity in the present study were not as high as those reported by Garrett and Hinman (1969). They observed that carcass density was highly correlated to the chemical components of the empty body. Their values were -0.96, 0.93, and 0.92 for percentages of carcass fat, water, and nitrogen, respectively. Although the relationships were not as strong in the present experiment, we did observe the strongest relationship for specific gravity when compared among the three methods. The ability of the present experiment to estimate the percentage of each component was in agreement with previous reports. For example, Lunt et al. (1985) concluded that the

use of animals with varying degrees of fatness influenced the ability of specific gravity to accurately estimate mean components. Similarly, the present experiment was designed to measure carcass composition of steers with varying degrees of fatness, which might have resulted in the poorer relationships than those observed when all cattle are slaughtered at finishing. It is likely that this method would have been more effective when comparing animals with similar body composition. Prediction equations relative to the present data were developed and are displayed in Table 7.

Theoretically, the 9-10-11 rib section is an accurate estimator of the chemical composition of the carcass (Hankins and Howe, 1946). Powell and Huffman (1968) and Lunt et al. (1985) reported successful prediction of chemical composition with the 9-10-11 rib section. Powell and Huffman (1968) found that the 9-10-11 rib section strongly predicted carcass chemical composition ($R^2 = 0.94$ for fat and $R^2 = -0.96$ for crude protein). In the present experiment, the relationship between proximate analysis of the 9-10-11 rib section and carcass composition was significant, but not as accurate as the values obtained by previous reports (Hankins and Howe, 1946; Powell and Huffman, 1968; and Lunt et al., 1985). Carcass prediction equations were developed for the 9-10-11 rib section and are displayed in Table 7.

One possible error associated with the 9-10-11 rib section method may have been variation between samplings. Variation associated with sampling during collection, preparation, and lab analysis may have contributed to the error in calculated data. One possible error may have been the extent to which the dissected components were handled and sampled in preparation analysis and lastly, for the final grinding. Had the samples

been handled in the same manner as the carcass samples, perhaps the analyses would have produced comparisons that were more accurate.

One objective of this study was to evaluate DXA as a potential method to estimate the composition of the 9-10-11 rib section. This would be more cost effective than dissection and proximate analysis. Our data suggests that the DXA scan was a moderately accurate estimator of 9-10-11 rib section composition. Lukaski et al. (1999) reported that one error associated with DXA was the inaccuracy of scans generated on thick tissues. The coefficients of determination produced from the relationships between percentages of lean and fat between the actual chemical composition of the rib and DXA were 0.69 and 0.71, respectively. With moderate modifications to account for bone density, fatness, and tissue depth, the DXA scan may be a valuable tool in future body composition estimation.

Due to the variation in live weight, empty body weight was used to measure urea space. This was an attempt to eliminate gastrointestinal fill as a factor. Bartle et al. (1987) used both empty body weight and live weight to predict body composition, and showed that empty body weight produced less error in the estimate. Therefore, empty body weight may be a more accurate variable of measure. The present experiment utilized the 12-min sample to calculate the urea space value. Kock and Preston (1979) suggested that this was the point at which urea has equilibrated into the body. These specifications of measurement did not aid in a successful attempt at urea space estimation in the present experiment. When analyzing the data, the highest concentration of plasma urea within individual experimental unit was not consistent with the 12-min sample, but also occurred at the 9-min and 15-min samplings. If the highest concentration of plasma

urea had been used to calculate urea space, perhaps the calculation would have produced a more reliable value for estimation.

Conclusion

The present data suggests that urea space is an inconsistent method, which may be influenced by a number of factors. Bartle et al. (1987) emphasized that for a method to be useful, it must be repeatable. Their study showed a relationship whereas the present study did not, with the relationship of urea space predictions of fat and crude protein having a slope not different that zero. Our data suggests that results from the urea space technique might be inconsistent.

Having reviewed the wide variety of techniques available to estimate empty body and carcass composition, the most significant problem appears to be consistency. Thus far, the aforementioned have been evaluated and re-evaluated by a plethora of researchers. The specific gravity technique has been evaluated by Garrett and Hinman (1969), Gil et al. (1970), and Johnson et al. (1990). The 9-10-11 rib section has been researched by Hankins and Howe (1946), Powell and Huffman (1968), and Lunt et al. (1985). Urea dilution has been evaluated by Preston and Koch (1973), Koch and Preston (1979), Meissner et al. (1980), Bartle et al. (1983), Hammond et al. (1984), Rule et al. (1986), and Bartle et al. (1987). For one or more of these methods to be utilized, the data must be repeatable and reliable. The methods of collection, preparation, and analysis of samples needed to validate these methods should continue to be improved.

The ability to estimate body composition is crucial to food animal research. Thus far, researchers have been unable to develop and agree upon a precise alternative to total

chemical analysis. Future research and development should focus on new technology, while continuing to improve the available technology that has been evaluated during the past century.

Table 1. Equations used to estimate empty body and carcass composition.

Urea space to predict empty body composition	Estimating equations
Moisture, %	$Y = 13.0 + 0.81x$[a]
Fat, %	$Y = 80.0 - 1.06x$[a]
Nitrogen, %	$Y = 0.93 + 0.034x$[a]
9-10-11 rib section to predict total carcass composition	
Moisture, %	$Y = 16.83 + 0.75x$[b]
Fat, %	$Y = 3.49 + 0.74x$[c]
Protein, %	$Y = 6.19 + 0.65x$[b]
Specific gravity to predict total carcass composition	
Moisture, %	$Y = 375.20x + 343.80$[d]
Fat, %	$Y = 587.86 + 530.45x$[d]
Nitrogen, %	$Y = 49.54 - 43.63x$[d]

[a]Bartle et al. (1987), where x represents urea space on an empty body basis.
[b]Hankins and Howe (1946), where x represents the percentage of each chemical component.
[c]Bruns et al. (2004), where x represents the percentage of fat.
[d]Garrett and Hinman (1969), where x represents specific gravity.

Table 2. Mean body weight, carcass weight, and carcass composition, between slaughter groups.

Item	Initial (n = 4)	Growing (n = 18)	Finishing (n = 24)	SEM	*P*-value
BW, kg	269.06[c]	387.12[d]	590.93[e]	24.43	0.001
HCW, kg	140.31[c]	223.75[d]	369.56[e]	14.54	0.001
CCW, kg[a]	134.98[c]	217.08[d]	360.62[e]	14.37	0.001
Water, %	56.82[d]	57.94[d]	53.34[e]	1.57	0.001
Water, kg	77.87[c]	125.7[d]	192.14[e]	1.27	0.001
Fat, %	17.88[c]	19.19[c]	25.93[d]	2.01	0.001
Fat, kg	23.50[c]	41.89[d]	93.70[e]	8.20	0.001
Ash, %	7.00[c]	6.36[c]	5.90[d]	0.35	0.008
Ash, kg	9.46[c]	13.75 [d]	21.33[e]	8.03	0.001

[a]CCW = cold carcass weight.

[c,d,e]Means within row that do not have a common superscript are different, $P < 0.05$.

Table 3. Component means estimated from carcass prediction methods.

	Method[a]					
Item	PA	US	SG	RIB	SEM	*P*-value
Water, %	54.21[b]	57.66[c]	54.89[b]	57.37[c]	0.91	0.001
Water, kg	126.85[b]	137.54[c]	127.68[b]	135.56[c]	38.82	0.001
Fat, %	19.24[b]	20.44[c]	23.44[c]	20.88[b]	1.13	0.001
Fat, kg	47.55[b]	50.26[b]	60.81[c]	53.51[b]	3.57	0.001

[a]PA = carcass proximate analysis; UD = urea space based on empty body weight; SG = specific gravity on left side of carcass; RIB = 9-10-11 rib proximate analysis.

[b,c]Means within rows that do not have common superscripts differ, $P < 0.05$.

Table 4. Component means between slaughter groups, estimated from carcass prediction methods.

	Initial (n = 4)					Growing (n = 18)					Finishing (n = 24)				
Item	PA[a]	US[a]	SG[a]	Rib[a]	SEM	PA	US	SG	Rib	SEM	PA	US	SG	Rib	SEM
% CP[b,c,d]	23.13[e]	-	17.94[f]	18.80[f]	0.75	19.91[e]	17.71[f]	17.48[f]	17.24[f]	0.39	18.36[e]	17.01[f]	15.65[g]	14.46[h]	0.31
CP, kg[b,c,i]	31.31[j]	-	24.22[k]	25.21[k]	2.62	43.22[e]	38.29[f]	37.92[f]	37.33[f]	1.32	65.70[e]	61.37[f]	56.25[g]	51.81[h]	1.09

[a]PA = carcass proximate analysis; US = urea space based on empty body weight; SG = specific gravity on left side of carcass; Rib = 9-10-11 rib proximate analysis.
[b]Slaughter group effect, $P < 0.001$.
[c]Method effect, $P < 0.001$.
[d]Slaughter group x method interaction, $P = 0.004$.
[e,f,g,h]Within slaughter group, unlike superscripts within row are different ($P < 0.01$).
[i]Slaughter group x method interaction, $P < 0.001$.
[j,k]Within slaughter group, unlike superscripts within row are different ($P < 0.05$).

Table 5. Estimation of component means of the 9-10-11 rib sections, between slaughter groups, by various methods.

	Initial (n = 4)				Growing (n = 18)				Finishing (n = 24)			
Item	Analysis[a]	DXA[b]	Dissection[c]	SEM	Analysis	DXA	Dissection	SEM	Analysis	DXA	Dissection	SEM
Rib weight, kg[d,e]	2.00	2.05	2.00	0.31	3.86[f]	3.92[g]	3.86[f]	0.15	6.65[f]	6.53[g]	6.65[f]	0.13
Fat, %[d,e,h]	17.94[f]	18.56[f]	12.64[g]	2.80	20.24[f]	23.78[g]	16.86[i]	1.32	31.00[j]	41.04[k]	32.86[l]	1.14
Fat, kg[d,e,h]	0.36	0.40	0.26	0.22	0.77[j]	0.94[k]	0.66[j]	0.10	2.03[j]	2.69[k]	2.21[l]	0.09
Lean, %[d,e,h]	75.64[f]	75.84[f]	59.95[g]	2.71	73.89[j]	70.92[j]	58.44[k]	1.28	63.17[j]	54.55[k]	47.99[l]	1.11
Lean, kg[d,e,h]	1.51[j]	1.54[j]	1.19[k]	0.19	2.87[j]	2.78[k]	2.25[l]	0.09	4.27[j]	3.55[k]	3.17[l]	0.08
Ash, %[d,e,h]	6.43	5.52	-	0.56	5.88[f]	5.48[g]	-	0.24	5.42	4.37	-	0.2
Ash, kg[e,n,o]	0.13	0.12	-	0.02	0.22	0.21	-	0.01	0.35[f]	0.28[g]	-	0.01

[a]Chemical analysis of the 9-10-11 rib section.
[b]Dual-Energy X-Ray absorptiometry of the 9-10-11 rib section.
[c]Physical dissection of the 9-10-11 rib section.
[d]Slaughter group x method interaction, $P < 0.001$.
[e]Slaughter group effect, $P < 0.001$.
[f,g,i]Within slaughter group, unlike superscripts within row are different ($P < 0.05$).
[h]Method effect, $P < 0.001$.
[j,k,l]Within slaughter group, unlike superscripts within row are different ($P < 0.01$).
[m]Slaughter group effect, $P < 0.006$.
[n]Method effect, $P < 0.03$.
[o]Slaughter group x method interaction, $P < 0.008$.

Table 6. Regression equations relating 9-10-11 rib prediction methods to actual chemical composition

	Lean (%)[a]				Fat (%)			
Item	Intercept	Slope	$S_{x.y}$	R^2	Intercept	Slope	$S_{x.y}$	R^2
DXA scan of rib section	33.29 ± 3.84	0.576 ± 0.060	4.25	0.67	5.65 ± 1.97	0.599 ± 0.058	4.23	0.71
Dissection of rib section	27.03 ± 4.93	0.799 ± 0.092	4.52	0.63	9.13 ± 1.54	0.644 ± 0.058	4.00	0.74

[a]The lean component represents crude protein and water.

Table 7. Prediction equations derived to estimate carcass composition from indirect methods.

9-10-11 rib section to predict total carcass composition	Prediction equations
Fat, %	$y = 8.18 \pm 1.45 + 0.493 \pm 0.054$(rib fat; $P < 0.001$) $S_{y \cdot x} = 2.85$; $R^2 = 0.65$
CP, %	$y = 13.78 \pm 1.09 + 0.374 \pm 0.071$(rib CP; $P < 0.001$) $S_{y \cdot x} = 1.59$; $R^2 = 0.39$
Specific gravity to predict carcass composition	
Moisture, %	$y = 237.45 \pm 41.93$(specific gravity; $P < 0.001$) $- 198.35 \pm 44.49$ $S_{y \cdot x} = 2.92$; $R^2 = 0.42$
Fat, %	$y = 428.54 \pm 40.56 - 384.22 \pm 38.22$(specific gravity; $P < 0.001$) $S_{y \cdot x} = 2.66$; $R^2 = 0.70$
CP, %	$y = 111.40 \pm 23.89$(specific gravity; $P < 0.001$) $- 98.83 \pm 25.35$ $S_{y \cdot x} = 1.66$; $R^2 = 0.33$

Figure 1. Relationship between carcass fat and predicted fat by urea space

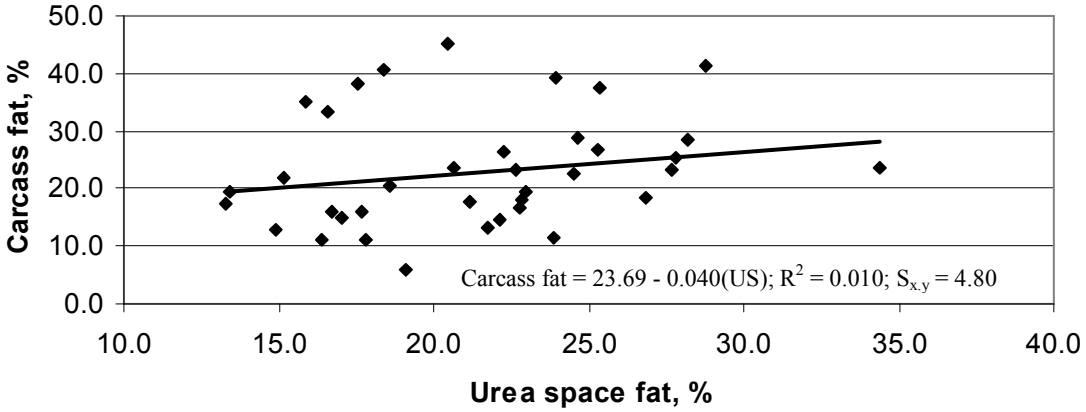


Figure 2. Relationship between carcass fat and fat predicted by specific gravity

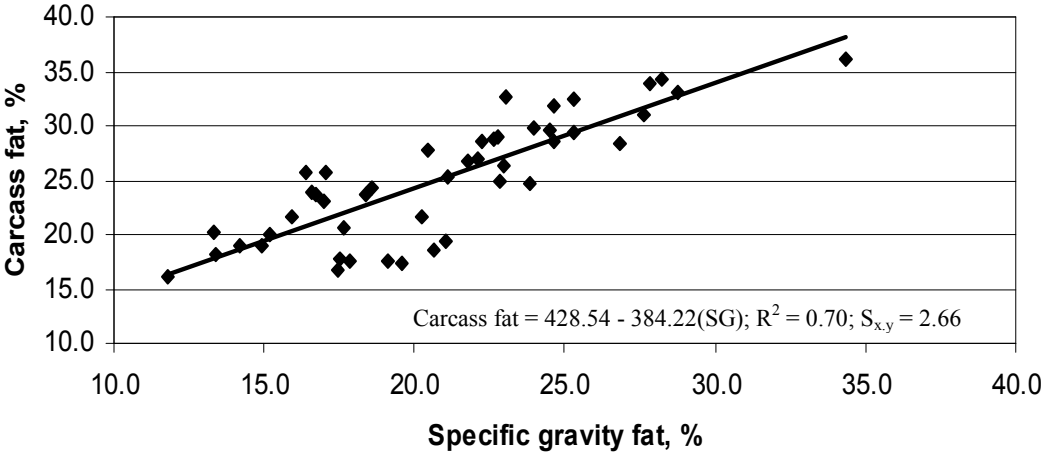


Figure 3. Relationship between carcass fat and fat predicted by the 9-10-11 rib section

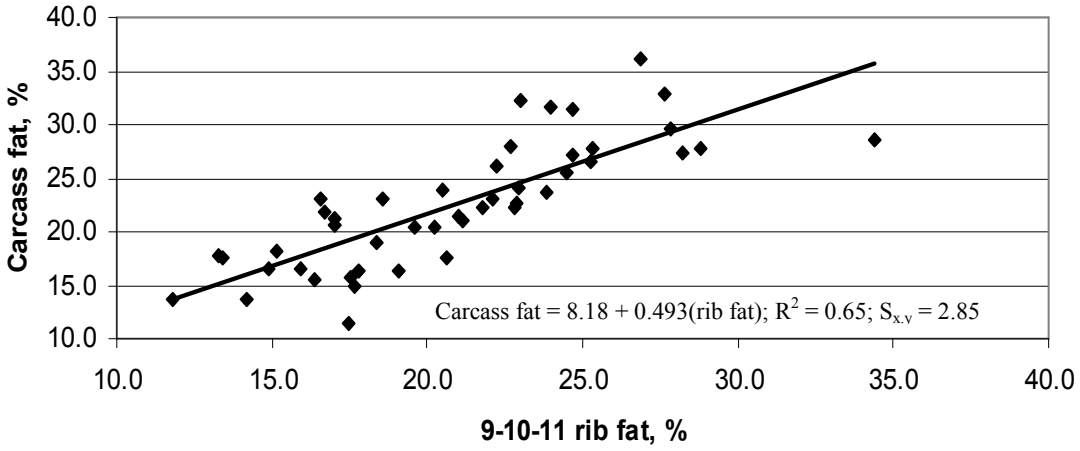


Figure 4. Relationship between carcass crude protein and crude protein predicted by urea space

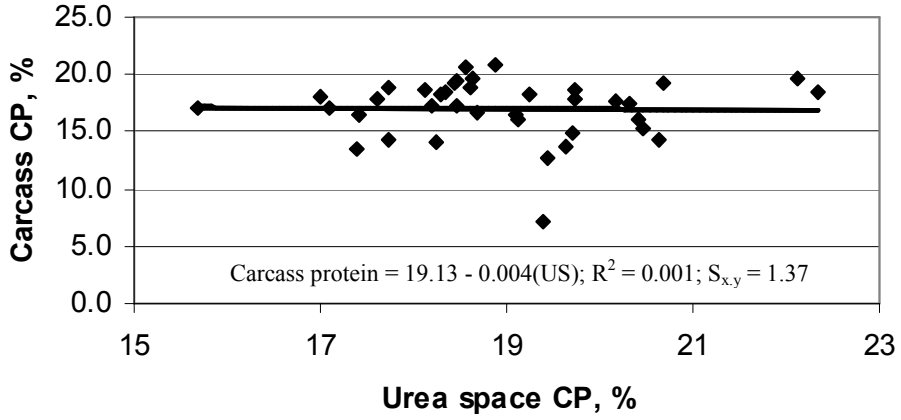


Figure 5. Relationship between carcass crude protein and crude protein predicted by specific gravity

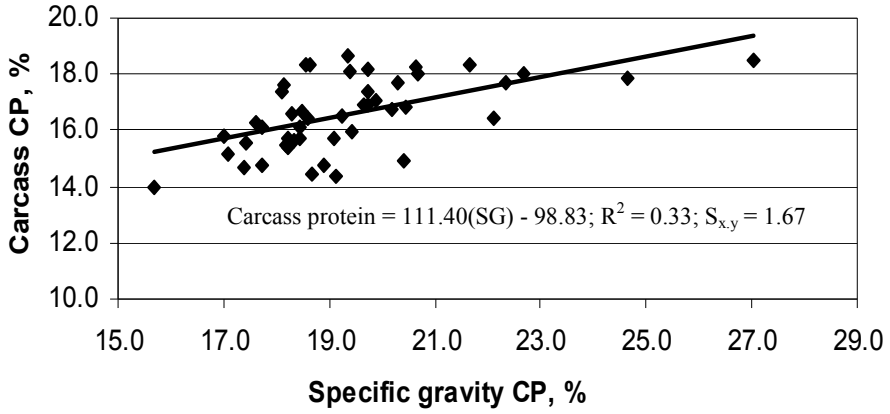
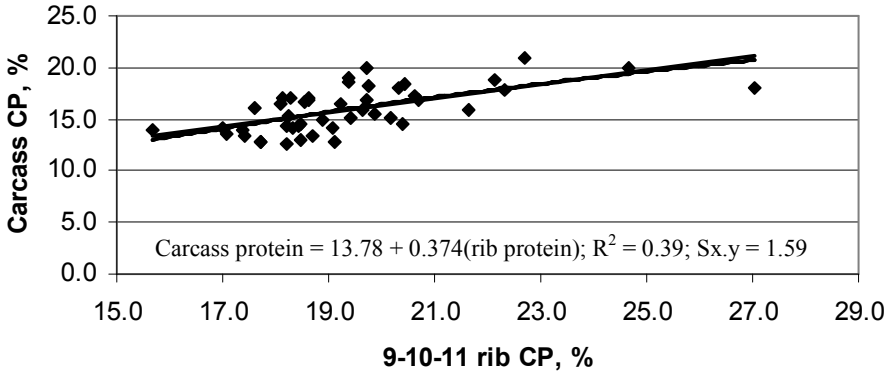


Figure 6. Relationship between carcass crude protein and predicted crude protein predicted by the 9-10-11 rib section



LITERATURE CITED

Alhassan, W. S., J. G. Buchanan-Smith, W. R. Usborne, G. C. Ashton, and G. C. Smith. 1975. Predicting empty body composition of cattle from carcass weight and rib cut composition. Can. J. Anim. Sci. 55:369-376.

Andrew, S. M., R. A. Erdman and D. R. Waldo. 1995. Prediction of body composition of dairy cows at three physiological stages from deuterium oxide and urea dilution. J. Dairy Sci. 78:1083-1095.

Andrews, F. N. 1958. Fifty years of progress in animal physiology. J. Anim. Sci. 17:1064-1078.

Bartle, S. J., S. W. Kock, R. L. Preston, T. L. Wheeler and G. W. Davis. 1987. Validation of urea dilution to estimate in vivo body composition n cattle. J. Anim. Sci. 64:1024-1030.

Bartle, S. J. and R. L. Preston. 1986. Plasma, rumen, and urine pools in urea dilution determination of body composition in cattle. J. Anim. Sci. 63:77-81.

Bartle, S.J., J.R. Males and R.L. Preston. 1983. Evaluation of urea dilution as an estimator of body composition in mature cows. J. Anim. Sci. 56:410-417.

Behnke, A. R., B. G. Feen and W. C. Welham. 1942. Specific gravity of healthy men. J. Am. Med. Assoc.118:495-501.

Blaxter, K. L. and J. A. F Rook. 1953. The heat of combustion on the tissues of cattle in relation to their chemical composition. British J. Nutr. 7:83-91.

Bruns, K. W., R. H. Pritchard and D. L. Boggs. 2004. The relationship among body weight, body composition, and intramuscular fat content in steers. J. Anim. Sci. 82:1315-1322.

Byers, F. M. 1979. Measurement of protein and fat accretion in growing beef cattle through isotope dilution procedures. Page 36 *in* Ohio Beef Cattle Res. Progress Rep. Anim. Sci. Ser. 79. Ohio Agr. Res. Dev. Ctr., Wooster.

Callow, E. H. 1948. comparative study of meat. II. The changes in the carcass during growth and fattening, and their relation to the chemical composition of the fatty and muscular tissues. J. Agr. Sci. 38:174-199.

Carstens, G. E., D. E. Johnson, M. A. Ellenberger and J. D. Tatum. 1991. Physical and chemical components of the empty body during compensatory growth in beef steers. J. Anim. Sci. 69:3251-3264.

Chauhan, S., W. W. K. Koo, M. Hammami, and E. M. Hockman. 2003. Fan beam dual energy x-ray absorptiometry body composition measurements in piglets. J. Am. College Nutr. Vol. 22, No. 5:408-414.

Fox, D. G. and J. R. Black. 1984. A system for predicting body composition and performance in growing cattle. J. Anim. Sci. 58:725-739.

Garrett, W. N. 1968. Experiences in the Use of Body Density as an Estimator of Body Composition of Animals. Pages 170-186 in Body Composition in Animals and Man. Natl. Academy of Sci. Pub. 1598.

Garrett, W. N. and N. Hinman. 1969. Re-evaluation of the relationship between carcass density and body composition of beef steers. J. Anim. Sci. 28:1-5.

Garrett, W. N., J. H. Meyer and G. P. Lofgreen. 1959. The comparative energy requirements of sheep and cattle for maintenance and gain. J. Anim. Sci. 18:528-547.

Gil, E. A., R. R. Johnson, V. R. Cahill, K. E. McClure and E. W. Klosterman. 1970. An evaluation of carcass specific volume, dye dilution and empty body parameters as predictors of beef carcass composition over a wide range of fatness. J. Anim. Sci. 31:459-469.

Hammond, A.C., D.R. Waldo and T. S Rumsey. 1990. Prediction of body composition in holstein steers using urea space. J. Dairy Sci. 73:3141-3145.

Hammond, A.C., T.S. Rumsey and G.L. Haaland. 1988. Prediction of empty body components in steers by urea dilution. J. Anim. Sci. 66:354-360.

Hammond, A. C. T. S. Rumsey and G. L. Haaland. 1984. Estimation of empty body water in steers by urea dilution. Growth 48:29-34.

Hammond, J. 1932. Growth and development of mutton qualities in the sheep. Oliver and Boyd, Edinburgh, Scotland.

Hankins, O.G. and P.E. Howe. 1946. Estimation of the composition of beef carcasses and cuts. USDA Tech Bull. 926: 1-20.

Hansard, S. L. 1968. Dilution Methods in Body-Composition. Pages 195-199 in Body Composition in Animals and Man. Natl. Academy of Sci. Pub.1598.

Heller, J., M. Kleinova, K. Janacek, and R. Rybova. 1984. Effects of sudden and a slow concentration increase in plasma urea on its concentration in some tissues of the dog and rat. Physiol. Bohemoslov. 33:296-302.

Hersom, M. J., G. W. Horn, C. R. Krehbiel, and W. A. Phillips. 2004. Effect of live weight gain of steers during winter grazing: I. Feedlot performance, carcass characteristics, and body composition of beef steers. J. Anim. Sci. 82:262-272.

Hopper, T. H. 1944. Methods of estimating the physical and chemical composition of cattle. J. Agr. Res. Vol. 68, No. 6:239-268.

Johnson, L.P., M.F. Miller, K.D. Haydon and J. O. Reagan. 1990. The prediction of percentage of fat on pork carcasses. J. Anim. Sci. 68:4185-4192.

Kock, S. W. and R. L. Preston. 1979. Estimation of bovine carcass composition by the urea dilution technique. J. Anim. Sci. 48:319-327.

Koo, W. W. K., M. Hammami, E. M. Hockman. 2004. Validation of bone mass and body composition measurements in small subjects with pencil beam dual energy x-ray absorptiometry. J. Am. College Nutr. Vol. 23, No. 1:79-84.

Kraybill, H. F., H. L. Bitter and O.G. Hankins. 1952. Body composition of cattle. II. Determination of fat and water content from measurement of body specific gravity. J. Appl. Physiol. 4:575-583.

Lukaski, H. C., M. J. Marchello, C. B. Hall, D. M. Schafer, W. A. Siders. 1999. Soft tissue composition of pigs measured with dual x-ray absorptiometry: Comparison with chemical analyses and effects of carcass thickness. Nutrition. Vol. 15, No. 9: 697-703.

Lunt, D.K., G.C. Smith, F.K. McKeith, J.W. Savell, M.E. Riewe, F.P. Horn and S.W. Coleman. 1985. Techniques for predicting beef carcass composition. J. Anim. Sci. 60: 1201-1207.

Lush, J. L. 1926. Practical methods of estimating proportions of fat and bone in cattle slaughtered in commercial packing plants. J. Agric. Res. 32:727-755.

McCurdy, M. P., C. R. Krehbiel, G. W. Horn, and J. J. Wagner. 2005. Effects of winter growing programs on subsequent feedlot performance, carcass characteristics and visceral organ mass of beef steers. Pages 120-121. Pub. No. AREC 05-20. Plains Nutrition Council Spring Conference.

McMeekan, C. P. 1940. Growth and development in the pig, with special reference to carcass quality characteristics. II. The influence of the plane of nutrition on growth and development. J. Agric. Sci. (Camb.) 30:387-443.

Meissner, H. H., J. H. Van Staden and E. Pretorius. 1980. In vivo estimation of body composition in cattle with tritium and urea dilution. II. Accuracy of prediction equations of the chemical analyzed carcass and non-carcass components. S. Afr. J. Anim. Sci. 10:165-173.

Mitchell, A. D., A. M. Scholz and V.G. Pursel. 2003. Prediction of pork carcass composition based on cross sectional region analysis f dual-energy x-ray absorptiometry (DXA) scans. Meat Science. 63:265-271.

Mitchell, A. D., A. M. Scholz, V. G. Pursel and C.M. Evock-Clover. 1998. Composition analysis of pork carcasses by dual-energy x-ray absorptiometry. J. Anim. Sci. 76:2104-2114.

Mitchell, A. D., M.B. Solomon and T.S. Rumsey. 1997. Composition analysis of beef rib sections by dual-energy x-ray absorptiometry. Meat Science. 47:115-124.

Mitchell, A. D., J.M. Conway and W. J. E. Potts. 1996. Body composition analysis of pigs by dual-energy x-ray absorptiometry. J. Anim. Sci. 74:2663-2671.

Murray, J. A. 1922. The chemical composition of animal bodies. J. Agr. Sci. 12:103-110.

NRC. 1996. Page 36 in Nutrient Requirements of Beef Cattle. 7th rev. ed. Natl. Acad. Press, Washington, DC.

Owens, F. N., D. R. Gill, D. S. Secrist, and S. W. Coleman. 1995. Review of some aspects of growth and development of feedlot cattle. J .Anim. Sci. 73:3152-3172.

Owens, F. N., P. Dubeski, and C. F. Hanson. 1993. Factors that alter the growth and development of ruminants. J. Anim. Sci. 71:3138-3150.

Powell, W. E. and D. L. Huffman. 1968. An evaluation of quantitative estimates of beef carcass composition. J. Anim. Sci. 27:1554-1558.

Preston, R.L. and S.W. Kock. 1973. In vivo prediction of body composition in cattle from urea space measurements. Proc. Soc. Exp. Biol. Med.143:1057-1061.

Preston, R. L. R. D. Vance, V. R . Cahill and S. W. Kock. 1974. Carcass specific gravity and carcass composition in cattle and the effect of bone proportionality on this relationship. J. Anim. Sci. 38:47-51.

Rathbun, E. N. and N. Pace. 1945. Studies on body composition. I. Determination of body fat by means of the body specific gravity. J. Biol. Chem. 158:667-676.

Reid, J. T., G. H. Wellington and H. O. Dunn. 1955. Some relationships among the major chemical components of the bovine body and their application to nutritional investigations. J. Dairy Sci. 12:1344-1359.

Rule, D. C., R. N. Arnold, E. J. Hentges and D. C. Beitz. 1986. Evaluation of urea dilution as a technique for estimating body composition of beef steers in vivo: Validation of published equations and comparison with chemical composition. J. Anim. Sci. 63:1935-1949.

Shebaite, M. K. 1977. Evaluation of water concept for in vivo composition. World Rev. Anim. Prod. 8:65-72.

USDA. 1935. Report of the chief of the bureau of animal industry. 55 pp.

Velazco, J., J. L. Morrill, D. H. Kropf, R.T. Brandt, Jr., D.L. Harmon, R.L. Preston, ad R. Clarenburg. 1997. The use of urea dilution for estimation of carcass composition of holstein steers at 3, 6, 9, and 12 months of age. J. Anim. Sci. 75:139-148.

Wagner, J. J. 1985. Carcass composition in mature Hereford cows: estimation and influence on metabolizable energy requirements for maintenance during winter. pp. 16-18. Ph. D. Diss., Oklahoma State Univ., Stillwater.

Wells, R.S. and R.L. Preston. 1998. Effects of repeated urea dilution measurement on feedlot performance and consistency of estimated body composition in steers of different breed types. J. Anim. Sci. 76:2799-2804.

Wuliji, T., A.L. Goetsch, R. Puchala, T. Sahlu, R.C. Merkel, G. Detweiler, S. Soto-Navarro, J. Luo, T. Shenkoru. 2003. Relationships between body composition and shrunk body weight and urea space in growing goats. J. Appl. Anim. Res. 23:1-24.

VITA

Rebecca Ann Ross

Candidate for the Degree of

Master of Science

Thesis: EVALUATION OF TECHNIQUES TO ESTIMATE CARCASS COMPOSITION OF BEEF CATTLE

Major Field: Animal Science

Biographical:

Personal Data:

Born in Austin, Texas on July 21, 1981. Daughter of Dr. and Mrs. Charlie P. Ross III.

Education:

Graduated from James Bowie High School, Austin, Texas, May 1999; Received a Bachelor of Science degree in Agriculture, Sam Houston State University, Huntsville, Texas, December 2003; Candidate for Master of Science Degree in Animal Science, Oklahoma State University, Stillwater, Oklahoma.

Professional Experience:

Graduate Research and Teaching Assistant, Oklahoma State University, Department of Animal Science; January 2004 – October 2005.
Sales and Nutritional Feedlot Consultant, Cargill Animal Nutrition. High Plains; October 2005 – Present.

Professional Memberships:

American Registry of Professional Animal Scientists, 2004 – 2005
American Society of Animal Science, 2004 – 2005
Animal Science Graduate Student Association, OSU, 2004 – 2005
Reporter, 2005
Delta Tau Alpha, Agricultural Honors Society, SHSU, 2002 – 2003

Name: Rebecca Ann Ross **Date of Degree**: December, 2005

Institution: Oklahoma State University **Location**: Stillwater, Oklahoma

Title of Study: EVALUATION OF TECHNIQUES TO ESTIMATE CARCASS COMPOSITION OF BEEF CATTLE

Pages in Study: 53 **Candidate for the Degree of Master of Science**

Major Field: Animal Science, Ruminant Nutrition

Scope and Method of Study: Percentages of moisture, fat, protein, and ash were determined on 46 Angus x Angus-Hereford steers, by means of proximate analysis. Urea space, specific gravity, and 9-10-11 rib section proximate analysis were performed and values for moisture, fat and protein were estimated. The composition of the 9-10-11 rib section was determined by three methods: dissection, proximate analysis, and dual-energy x-ray absorptiometry.

Findings and Conclusion: Specific gravity produced the most precise comparison to chemical composition of the carcass (R^2=0.70 for fat and R^2=0.33 for CP). Similar relationships were derived between proximate analysis of the 9-10-11 rib section and carcass composition (R^2=0.65 for fat and R^2=0.39 for CP). Urea space was not successful as an indirect method of empty body composition estimation. The DXA scan was able to accurately predict the composition of the rib section (R^2=0.69 and R^2=0.71). In review of the results, the present study recommends further investigation and modification of the abovementioned methods.

ADVISER'S APPROVAL: Clinton R. Krehbiel